Model of Microwave Assisted Thermal Adhesion of Synthetic Leather to a Plastic Substrate

S. Soldatov[1], J. Meiser[2], B. Lepers[1], G. Link[1], J. Jelonnek[3]

[1]Karlsruhe Institute of Technology (KIT, IHM), Karlsruhe, Germany
[2]Carl Meiser GmbH & Co. KG, Albstadt, Germany
[3]Karlsruhe Institute of Technology (KIT, IHM, IHE), Karlsruhe, Germany

Abstract

The lamination of substrates with thin coatings is commonly used in furniture, automotive and avionic industries. In the lamination process the hot melt adhesives are widely used and typically activated at temperatures from 80 °C to 140 °C by resistive heating. This requires a heat transfer through the coating and/or the substrate. To make the process more flexible, to decrease its energy consumption and to shorten the processing time, the replacement of conventional heating by a volumetric and selective microwave heating (Fig. 1) is investigated in the present work.

A sandwich structure consists of a polymer substrate, PVC artificial leather and adhesive between them, which is compressed by vacuum bag. The glue is patterned at a wrong side of the coating in the form of dots. The model is limited to a cylinder whose axis is perpendicular to the coating and substrate surfaces and a glue domain is positioned symmetrically on the axis (Fig. 2). We neglect thermodynamic interactions between neighboring glue domains and pose "Open Boundary" condition at the lateral side of calculated area. The following equation for each domain is solved:

$$\rho \cdot c_p \cdot \partial T/\partial t = \nabla \cdot (k \nabla T) + p_{abs},$$

where ρ, c_p, k , and p_{abs} denote the mass density, specific heat, thermal conductivity, and microwave absorbed power density, respectively. The internal heat sources due to absorbed microwave power in the coating, glue and substrate domains depend on temperature:

$$p_{abs}(T)=2\pi \cdot f \cdot \epsilon_0 \cdot \epsilon''(T) \cdot E_{rms}^2.$$

f, ϵ_0, E_{rms} and $\epsilon''(T)$ are the frequency, vacuum permittivity, root-mean-square of electric field and dielectric loss factor, respectively. The absorbed power densities p_{abs} in the materials correspond to a power of 7.68 kW coupled to the HEPHAISTOS [1] microwave oven for about 100 s. After 88 s of heating the temperature in the glue domain exceeds 100°C but the temperature in the PVC leather is above its damage limit of 80°C (Fig. 3). This motivates the optimization of the above approach with the aim to decrease the heat loads in the coating material as much as possible.

The optimization of the boundary condition at the upper side of the vacuum bag and the thermal properties of the coating material allow to achieve the targeted temperature profile in the investigated sandwich structure for a time shorter than 60 s.

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Reference

[1] http://www.voetsch-ovens.com/en/products/industrial_microwave_system/schunk01.c.59509.en

Figures used in the abstract

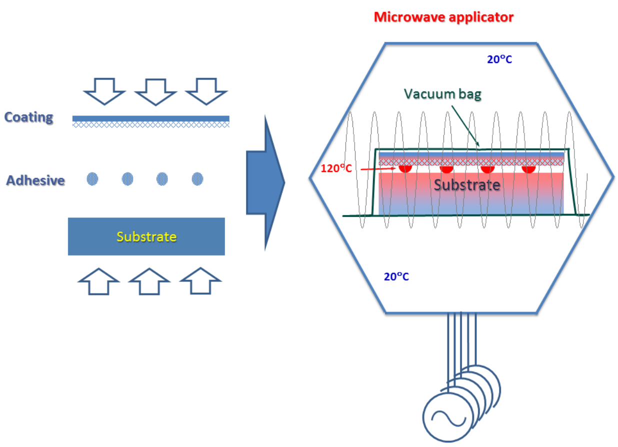

Figure 1: Scheme of microwave assisted bonding of a thin coating to a substrate with hot melt adhesives.

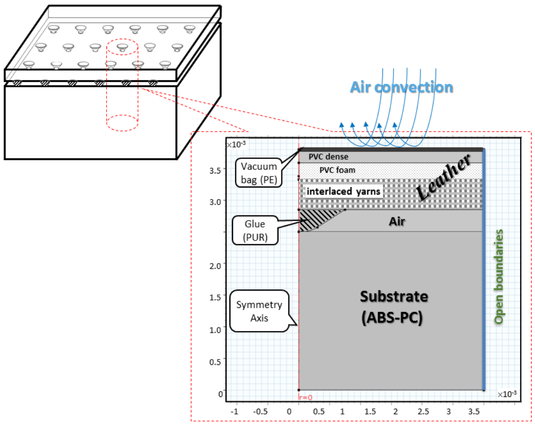

Figure 2: The distribution of glue dots between substrate and coating (upper left). The simulated sandwich structure (lower right).

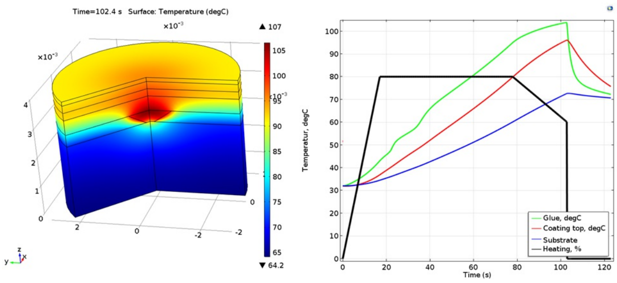

Figure 3: Temperature fields within sandwich structure after 102.4 s of heating (left). Temperature evolution in three domains (right).